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FINAL REPORT

PRODUCTION ENGINEERING STUDY - HG-3 HANDCRANK GENERATOR

[redacted] W.O. 673)

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Reference: [redacted] Technical Proposal
Dated January 11, 1960

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Submitted by

[redacted]

STAT

Project Engineer

August 19, 1960

DOC 16 REV DATE 12/4/80 BY 37169
ORIG COMP 33 OPI 56 TYPE 30
ORIG CLASS U PAGES 34 REV CLASS U
JUST _____ NEXT REV _____ AUTH: HR 70-2

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PRODUCTION ENGINEERING STUDY - HG-3 HANDCRANK GENERATOR

PURPOSE

The purpose of this project was to conduct an engineering study of the general design and construction features of the HG-3 handcrank generator and to develop more efficient fabrication methods and tooling such that economical production of the device in comparatively small quantities could be carried out. In accordance with this Laboratory's technical proposal dated January 11, 1960, a production cost of $350 per unit and a $30,000 tooling expenditure were established as project goals. A complementary objective of the project was the construction of two prototype models of the generator as they would be supplied under the proposed production methods for submission to the Government for evaluation and test.

SUMMARY

The production engineering study of the HG-3 handcrank generator has resulted in the attainment of a substantially lower unit cost in comparatively small production quantities at a modest expenditure for tools. A unit price for lots of 200 of $325 has been realized for an expenditure of $32,000 in tooling. The expenditure for tooling is $2000 higher than the goal of the project, which was at best a careful estimate, but this increase is more than compensated by the decrease in $25 per unit from the $350 unit price goal given in the proposal. Therefore, it is felt that the overall object of the project, the economical production of the HG-3 generator in reasonable quantities, has been met.

The majority of the cost reduction in the generator has resulted from the substitution of molded plastic material for the considerably more expensive machined parts such as the micarta end bells, the fiberglass case, the stainless steel backplate, etc. Other important economies were made by incorporation of a simpler crank handle socket assembly, indicator lamp assembly, mounting fixtures, and gear box configuration. In the electrical phase, reductions were attained by the substitution of less expensive components, such as silicon diodes, a different relay, a smaller filter capacitor, and replacement of a very expensive miniature milliammeter with a transistor-driven indicator lamp circuit. In addition a modified printed

circuit was incorporated which will reduce the electronic assembly cost considerably.

It is felt that the performance of the generator has in no way been compromised by these material and component modifications. Performance tests on the two prototype units indicate electrical output characteristics equal to or better than the eight models produced under the development contract. In certain areas the changes made have improved the strength and wear factor of the generator and it will certainly be agreed that the overall appearance presents a far higher degree of workmanship. By changing the layout of the electronic assembly, the maintenance factor of the unit has been vastly simplified through the elimination of connectiong harnesses between the top and bottom of the case and the electronics. The entire electronics package now lifts out by simply disconnecting the generator coil and output leads.

The two prototype units called for in the contract have been completed and shipped to the Government for evaluation. They are, in essence, of the same construction as would be produced by this Laboratory under a production contract, except for minor modifications which have been covered by separate correspondence to the Government's technical representative. A complete and detailed price analysis showing unit cost breakdown, piece prices and tool costs, has been prepared and is attached to this report as Appendix A. Three complete sets of manufacturing drawings showing complete manufacturing

information for each part plus assembly data are also being supplied as called for under the terms of the contract. These drawings, plus the price information, will aid the Government in determining the major cost areas in the proposed unit and also offer a very accurate representation of component and assembly features, material, and construction detail.

At the start of the project a detailed study was made of the original method of manufacture for the HG-3 handcrank generator. It became increasingly evident during this study that to produce the unit in the same fashion as the eight prototype units built under the previous contract, a cost of approximately $600 would have resulted. Therefore, the production study has resulted in a net unit cost reduction of $275 which, in the event of supplying 200 generators to the Government, would more than justify the cost of the study and the tooling involved. Any further procurement, of course, would further increase the overall savings in money proportionately. It is therefore concluded that the project has been successful and has justified the expenditure of the time and money involved.

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DETAILED DISCUSSION

A. General

In the brief investigation made during the preparation of the proposal for the subject project, it was determined that the greatest area of cost reduction in the hand-crank generator as made under the previous contract would be attained by the substitution of molded parts for the comparatively expensive machined pieces, such as the case, end bells, etc. It was also felt, however, that a further worthwhile saving could be made through an intensive review of the electrical system to determine the possibility of substituting different parts for rather expensive components, such as the filter capacitor, relay, etc. Therefore, upon receipt of the contract, the investigation was divided into two primary phases, namely a mechanical study to determine more economical methods of parts fabrication and an electrical study to review the circuitry and components for possible economies.

Upon completion of the electrical study, a third phase was initiated in which a more simple packaging assembly, both electrical and mechanical, was devised. Experience in assembling the eight prototype models under the previous contract had shown that a worthwhile cost reduction was possible in this area and had also suggested various paths by which simpler assembly costs could be attained.

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The following section will briefly describe the various modifications made during these phases and their effect in reducing the cost.

B. Mechanical Modifications

The mechanical cost study was initially directed at five general areas of disproportionate expense which were as follows:

1. The case, which in the prototype models had been made of a fiberglass reinforced polyester molded construction, was redesigned to use a molded material known as Kralastic. The previous case, while having a very good wear and strength factor, had been quoted at $48 each in quantities of 200 and was found to be very difficult to manufacture with respect to dimensional tolerances. It was felt that the Kralastic would have the same strength, could be manufactured to a very close tolerance, and would only cost a matter of a few dollars per unit, not counting, of course, the cost of the mold.

2. The end bells for the generator unit and transmission had been machined from micarta and found to be very expensive to produce, costing from $20 each for the smaller section to $60 to $70 each for the larger piece. These parts were redesigned to have a simpler configuration and to be molded from a material known

as Diall FS-4. This is a very stable plastic having very good strength characteristics, and again resulted in a large price reduction.

3. The fixtures for wall or table mounting in the initial models had been made from stainless steel involving a complexity of parts, all of which had to be machined from this rather expensive material. It was reasoned that a new mounting method could be devised by employing a molded plate which would contain all the various mounting details. Installation would then be carried out by simply mounting the plate first and slipping the generator into it, rather than having to have additional mounting means on the generator case as well. This not only resulted in a sizable cost reduction, but effected a rather significant reduction in weight.

4. The entire handle mechanism and receiving socket assembly in the previous unit were quite expensive to manufacture, particularly due to a broaching operation in the main hub plus the use of aluminum parts in the handle. Here, again, the handle was changed to a molded material and the engaging assembly was completely redesigned to allow much simpler manufacturing methods.

5. The original unit used nylon gears which were staked to stainless steel pinions, again a comparatively

expensive assembly. These were redesigned (except for the stainless steel pinion common with the rotor) to be molded from Delrin as integral pairs. In other words, for the first and second stages the pinion and drive gear are molded as one complete unit. The mold manufacturer, incidentally, states that these gears could be run without lubrication, which, in turn, eliminated the need for any housing or shields to contain a lubricant.

The above changes were carried out and found to result in not only a large cost reduction, but to give assurance of better and more uniform parts. In addition, there were other mechanical changes made, most of which were more minor in nature, but which also added to the overall reduction.

It is the conviction of this Laboratory that the performance of the generator has in no way been compromised by the changes made. In fact, it is predicted that the overall performance, reliability, and endurance of the device will be improved by these changes in comparison with the results that would have been expected using the previous methods.

Complete and absolute evaluation has not been attempted by this Laboratory because of both the critical delivery situation of the two units constructed and the fact that it is more practical for the customer to perform this work in view of the life test specified and the shock and vibration requirement, parameters for which have never been actually

established. While this Laboratory recommends that these units be put through full evaluation procedure, it should be borne in mind that the molded parts supplied in the two units were machined from sample blocks of the material, rather than actually being molded in the new configuration. This, of course, tends to cut down some of the strength factor, but it is felt that the units will still meet the specifications and, therefore, actual production units would have an even greater margin of safety.

C. Electrical Investigation

In reviewing the electrical design of the HG-3 hand-crank generator, it was felt that the greatest economy would be realized in the following areas:

1. Elimination of the very expensive 1200 mfd. tantalum capacitor by substitution of a cheaper type or reduction to a lower value of capacity.
2. Substitution of a simpler relay.
3. Substitution of the Marion subminiature milliammeter by a different indicating means.
4. Procurement of less expensive transistors.

In addition to the above, certain of the other components were re-examined to see if they could be replaced by less expensive units and this additional study proved quite fruitful. There had been some objection to the use of the 8 germanium diodes, particularly since it was so

difficult to mount them firmly and also because they were being used on a duty cycle in excess of their published ratings. This investigation resulted in the procurement of very inexpensive high current silicon diodes which made possible a 4 diode bridge, decreasing the space required, and actually reducing the cost of the overall rectifier assembly. While it is true that the silicon rectifier is somewhat more inefficient than the germanium, it is felt that the minor additional dissipation is more than compensated by the increased reliability and simplicity.

In connection with the first item above, the filter choke was rewound with more turns of a small diameter wire, again at a slight increase in dissipation, and resulted in a sufficient increase in inductance to permit the reduction of the capacitance required for adequate filtering from 1200 mfd. down to approximately 500 mfd. Aluminum filter capacitors were then investigated but, because of their instability with temperature, were discarded in favor of 2 small tantalum capacitors connected in parallel, the total cost of which was approximately one-third that of the original 1200 mfd. capacitor. Since the choke with the increased turns was no more expensive to manufacture, this resulted in a price reduction of $20 per unit.

A brief survey of the relay field showed that a very good compromise was available in the form of the Allied Control Type T-154 miniature relay in place of the

more expensive microminiature crystal can General Electric relay. While reliability is important for this component, it is, nevertheless, a device which can be expected to operate only a few times in the life of the generator and does not require the performance criterion that might normally be expected in the case of many relay applications where operation of 100,000 cycles or better is common. The substitution of the Allied Control relay resulted in a 75% price reduction and, although somewhat larger in size, presented no packaging problem since the additional space was made available by the smaller rectifier stack described above. Another advantage resulted from the use of this relay in that its increased sensitivity made possible the substitution of a lower rated diode in the circuit which energizes the relay in the event of reverse polarity.

Since the initial development of the HG-3, one of the most obvious cost features has been due to the use of the Marion subminiature milliammeter which indicates rate of charging current. Since there is no less expensive meter of this size on the market, a study was initiated towards the development of some other current-indicating means which would reduce this severe cost. This resulted in the development of a transistor-driven lamp circuit in which the output current flow through a 0.5 ohm resistor results in a bias voltage on the base of an

inexpensive switching transistor, turning on a small incandescent lamp. To provide an extended range, a diode was placed in the base of the transistor such that no light would result in currents up to 0.5 ampere. From this value upward, the light from the lamp increases in intensity until at one ampere, it levels off to a steady value. This operation, therefore, gives approximately the same indication as the meter in the previous unit, and was considered a satisfactory means. While it is true that the lamp intensity is not particularly sharp between 0.5 and 1.0 ampere, it is also true that it is quite difficult to crank the generator at this rate, the natural inclination being to crank at 50 - 60 revolutions per minute or better. Therefore, the circuit becomes, in practice, a one ampere indicator just as the meter was and should present no difficulty in operation. In making this change, a cost reduction of over 75% was realized, since the Marion meters were quoted at a price of approximately $18 in quantities of 200. Further, it should be noted that the subminiature milliammeter has always been a rather delicate device which must be handled with extreme care in assembly and, in addition, presented a severe problem in mounting securely to the case. Therefore, the actual cost reduction is even greater when one considers the increased ease of assembly made possible by this change.

Additional study of the general electronics circuitry resulted in further reductions by the procurement of the less expensive 2N226 transistors in place of the previous 2N536 transistors. In addition, the 1N677 high conduction diodes were replaced by the lower rated DR326 diodes, a change made possible by the substitution of a more sensitive relay as stated above. The revised and up-to-date circuit diagram is shown in Fig. 1.

Upon procurement of the various new parts and development of the new circuitry, the generator electronics was breadboarded, tested, and found to give the same performance characteristics as had been attained with the previous prototype models. Undoubtedly, a slight decrease in efficiency has been engendered by the substitution of the silicon diodes and the less efficient choke, but it is felt that this will be almost unnoticeable in manual operation and is well justified by the resulting cost reduction. The electrical performance characteristics for the two production-type units are shown in Fig. 2. It will be noted that the results are very close to those figures obtained with the eight models produced under the previous contract.

D. Packaging

The assembly and packaging of the electronics in the HG-3 handcrank generator, as designed under the development

contract, was found to be a costly procedure due for the most part to the necessity for connecting harnesses and leads to the indicating lights and meter in the generator cover and the generator windings respectively. In addition to being a problem in production, this type of assembly would make the field maintenance of the generator somewhat difficult. After considerable study, it was found that the substitution of the transistor-driven lamp indicator for the Marion milliammeter would not only give a cost reduction on the basis of their relative prices, but would also permit the elimination of the connecting harness to the cover. This was accomplished by mounting the three indicator lights in the electronic package and having them protrude through plastic holders integral with the cover. Therefore, all necessity for leads to the cover was eliminated and, incidentally, makes lamp replacement quite simple.

With the substitution of the 4-diode silicon bridge rectifier and the smaller filter capacitor, it was found that more space was now available for the electronics. This increase allowed a change to a modified print circuit type of configuration in which the interconnecting leads between components are furnished in the form of an etched circuit on the electronics cards, lowering the assembly cost quite considerably and increasing the reliability factor of the electronic circuitry.

Further important changes were made in the electronic package by the elimination of lead wires to the output terminal. Connection is now made by having two holes in the electronics cards which fit over the output studs, connection being made through washers and nuts to etched circuits on the cards. Further, the leads from the generator coils have been connected by screw terminals to the electronics package. These changes now enable the operator to take the electronics package out of the generator completely by undoing 4 screw-type-terminals and 2

mounting studs. In addition, the electronics package can now be assembled separately, tested out by simulation procedures, and installed in the unit with a minimum of cost for final check-out.

A further improvement was made by changing the electronic assembly to have one card instead of a stacked configuration, which makes any replacement of components a comparatively simple matter. Since the card can be completely removed, all components are easily exposed for test or replacement.

It is estimated that the various changes in packaging have reduced the assembly cost of the electronics package by between 50% and 70% from the original figure. They have also increased the maintenance ease of the unit greatly and undoubtedly added to the reliability and life of the device due to the elimination of a considerable amount of interconnecting wiring and a rather delicate milliammeter. The photographs in Appendix A show the details of these changes and will compare quite favorably with the units submitted under the development contract.

CONCLUSIONS

Submission of this report, together with the accompanying drawings and price analysis, will constitute completion of the project. It is the opinion of this Laboratory that the project has been successful in attaining the assigned goals by accomplishing the following:

1. It has been shown that with a moderate expenditure for tooling, the HG-3 handcrank generator can be produced at a price considerably lower than that quoted for the units as originally designed.
2. The modified design is felt to have considerable improvement with respect to operating life, quality of workmanship,

reliability, appearance, maintenance and ease of installation.

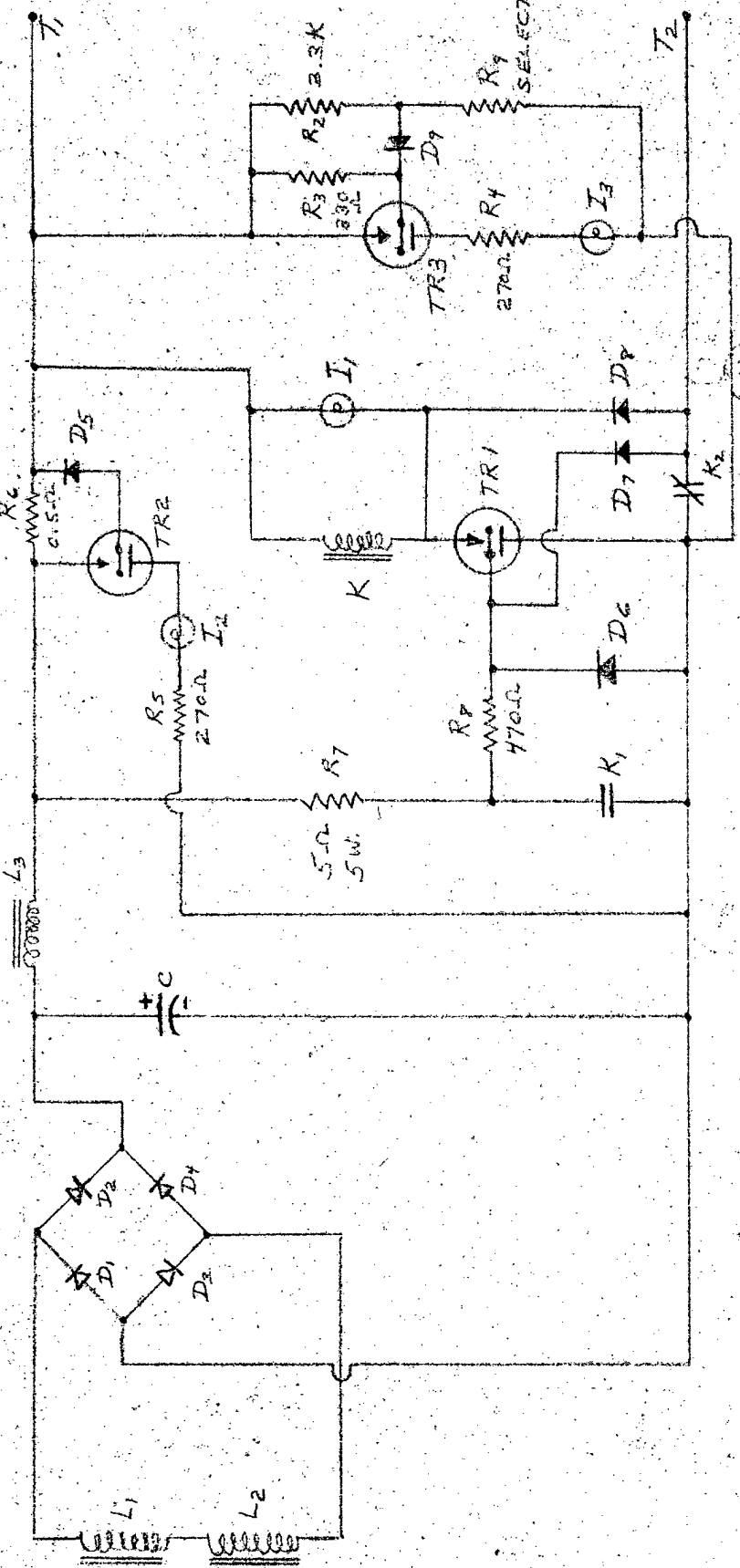
3. Two units of the redesigned generator have been constructed in the same fashion as they would be made under a production contract, for evaluation and test purposes by the Government which will aid in determining the justification of certain price reductions, acceptability, etc.

At the completion of the contract, a balance of $1,062.12 remained.

gs

BY _____ DATE _____ SUBJECT GENERATOR - CIRCUIT DIAGRAM SHEET NO. _____ OF _____

CHKD. BY _____ DATE _____ JOB NO. 673



1) L_1, L_2 - GENERATOR WINDINGS 490 ±5 t. #19 SF EA.

2) L_3 - FILTER CHOKE 190 t. #22 HF ON AL-71 CORE.

3) C - 2 - 870 MFD. TANTALUM CAPACITORS IN PARALLEL

4) K - T-154X-91 RELAY

5) D_1, D_2, D_3, D_4 - IN1692 DIODE

6) D_5 - DR435 DIODE

7) D_6 - IN1316A ZENER DIODE

8) D_7, D_8 - DR326 DIODE

9) D_9 - IN1315A ZENER DIODE

10) I_1, I_2, I_3 - #344 LAMP

11) TR1, TR2, TR3 - 2N222 TRANSISTOR

BY _____ DATE _____ SUBJECT PRODUCTION - TYPE UNITS - ELECTRICAL PERFORMANCE SHEET NO. _____ OF _____

CHKD. BY _____ DATE _____ JOB NO. 623

UNIT NO.	OUTPUT CURRENT AMPS.							
	BATTERY VOLTS	CRANKING RATE RPM						
		40	60	70	80	90	100	120
521	13.0	.78	1.03	1.08	1.10	1.12	1.13	1.14
	14.7	.66	.98	1.03	1.06	1.08	1.09	1.11
522	12.7	.75	1.01	1.05	1.06	1.08	1.08	1.09
	14.2	.66	.975	1.02	1.04	1.06	1.07	1.08

RIPPLE FACTOR (BOTH UNITS) @ 60 RPM = 1.35

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APPENDIX A

Cost Analysis

HG-3 Handcrank Generator

UNIT PRICE

Purchased Parts (per schedule)		$ 61.25
Fabricated Parts (per schedule)		53.51
Raw Material		10.00
Processing		5.00
Assembly (per schedule)		52.50
Test		6.00
Overage (spoilage, etc.) 10%		18.83
Inspection		20.71
	$	227.80
Engineering		27.66
	$	255.56
Contingency 5% (Due to first run)		12.78
	$	268.34
G. & A. 7.2%		19.32
	$	287.66
Profit		37.34
Total Unit Price	$	325.00

HANDCRANK GENERATOR

PURCHASED PARTS COST

Quantity	Part	Total Cost
4	INI692	$ 1.80
2	109D277X001570 Cap.	9.50
3	2N226 Transistors	2.25
3	344 Lamp	1.45
1	DR435 Germanium Diode	.80
2	270Ω 0.1 Watt Res.	.29
1	3.3KΩ 0.1 Watt Res.	.15
1	330Ω 0.1 Watt Res.	.15
1	0.1 Watt Res.	.15
1	T154x-91 Relay	2.05
1	INI315A Zener Diode	3.50
1	INI316A Zener Diode	3.50
1	470Ω 1/2 Watt Res.	.07
1	5 x 5 WL Res.	.37
2	Gen. Winding	4.92
2	9766-28 Binding Post	.42
1	Choke	6.43
2	DR326 Diode	1.22
2	Phone Tips	.18
4'-0"	8677 Wire	.20
2	#60 Alligator Clips	.08
3	SFR 188PP Bearing	7.62
2	SFR 168PPEE Bearing	5.40
2	SFR 168PP Bearing	5.40
3	1060-60-6 Nut	.15
3	1060-59-5 Lockwasher	.05
3	AN961-4 Washer	.06
10	H-240 Oval Hd. Rivet	.10
1	H-154 Oval Hd. Rivet	.03
2	H-154 Oval Hd. Rivet	.04
2	H-705 Flat Hd. Rivet	.04
2	H-703 Flat Hd. Rivet	.04
4	Flat Hd. Scr.	.08
4	Flat Hd. Scr.	.08
4	Flat Hd. Scr.	.04
3	Flat Hd. Scr.	.06
4	Flat Hd. Scr.	.08
1	Oval Hd. Scr.	.02
1	Round Hd. Scr.	.01
1	#2 Lock Washer	.01
7	3B-624 Clip	1.75
2	2500B Terminal	.08
2	100-200-16-8 Clip	.22
16	1D4-6B Post	.16
5	3DD4-48B Post	.05
2	# 2-56 Hex Nut	.06
2	# 2 Washer	.14
	Total	$61.25

FABRICATED PARTS COST

Print No.	Part	Unit Cost
1397-2-1	Lamination	$ 1.51
1397-2-2	Lamination	2.21
1397-11-1	Cover-Bottom	2.15
1397-21-1	End Bell	1.50
1397-23	Flange	1.90
1397-24-1	Stud	1.18
1397-24-2	Stud	1.16
1397-25-1	Shaft-Drive	5.95
1397-28	Spacer	.31
1397-35	Spacer	.30
1397-36-1	Crank	.28
1397-37-1	Handle	.57
1397-38-1	Shaft	.68
1397-42	Scr.-Captive	.85
1397-43	Gasket	.50
1397-60-1	Clip	.20
1397-61-1	Clip	.17
1397-66	Gear	1.20
1397-73-1	End Bell	2.20
1397-74	Plate	2.50
1397-75	Flange	2.38
1397-86-1	Lamp-Red	.45
1397-86-2	Lamp-Green	.45
1397-86-3	Lamp-White	.45
1397-92	Washer	.12
1397-93	Dowel	.80
1397-94-2	Cover-Top	2.00
1397-96	Shaft	4.90
1397-97	Hub-Rotor	3.50
1397-99	Bushing	.45
1397-101	Bearing	.90
1397-103	Seal	.04
1397-105	Mount	.32
1397-106	Isolator	.60
1397-112-2	Mounting Pl't.	1.75
1397-113	Bearing	.50
1397-153-1	Gear	.75
1397-154-1	Gear	.90
1397-162	Stud	.25
1397-163	Detent	.12
1397-164-1	Lock	.05
1397-165-1	Stud	.33

HANDCRANK GENERATOR

FABRICATED PARTS COST

Print No.	Part	Unit Cost
1397-166	Stud	$ .21
1397-171	Insert	.23
1397-172	Stud-Lamp	.24
1397-173	Retainer-Lamp	.30
1397-174	Bracket-Relay	.10
1397-175	Bracket	.19
1397-176	Spacer	.19
1397-177	Printed Cir.	1.92
1397-180	Name Plate	.20
1397-180-1	Name Plate	.20
1397-182	.5 ∿ Resistor	.15
1397-184	Pad.	.05
1397-185	Bracket	.20
	Total	$53.51

HANDCRANK GENERATOR

ASSEMBLY COST

Print No.	Part	Unit Cost
1397-A-1	Main Assem. (Final Assem.)	$ 3.00
1397-A-2	Top Cover Assem.	6.00
1397-A-3	Bottom Cover Assem.	.50
1397-A-4	Rotor Assem.	15.00
1397-A-5	Gear & Dr. Sh. Assem.	.50
1397-A-6	End Bell Assem.	1.50
1397-A-7	Crank Handle Assem.	.25
1397-A-8	Mounting Pl't. Assem.	.25
1397-A-9	Ter. Board Assem.	3.00
1397-A-10	Ter. Board & Wiring	12.00
1397-A-11	Harness	1.50
1397-A-12	Winding & Lam. Assem.	6.00
1397-A-13	End Bell-Gear & Lam. Assem.	3.00
	Total	$52.50

HG-3 Handcrank Generator

TOOLING QUOTATION

Manufacturing Tool Cost (per schedule)	$ 23,275.00
1397-A-4 Mold	500.00
Miscellaneous Assembly Fixtures	1,000.00
Miscellaneous Gages	500.00
Miscellaneous Test Equipment	2,000.00
	$ 27,275.00
G. & A. 7.6%	2,072.00
	$ 29,347.00
Profit	1,467.00
Total Tooling Cost	$ 30,814.00

HANDCRANK GENERATOR
TOOL COST

Print No.	Part	Type Tool	Tool Cost
1397-2-1	Lamination	Die	$ 165.00
1397-2-2	Lamination	Die	120.00
1397-11-1	Cover-Bottom	Mold	2,450.00
1397-21-1	End Bell	Mold	1,975.00
1397-23	Flange	Drill Jig	185.00
1397-24-1	Stud	Misc. Tools	68.00
1397-24-2	Stud	Misc. Tools	68.00
1397-25-1	Shaft-Drive	Misc. Tools	276.00
1397-28	Spacer	Misc. Tools	58.00
1397-35	Spacer	Misc. Tools	18.00
1397-36-1	Crank	Dies	913.00
1397-37-1	Handle	Mold	1,175.00
1397-38-1	Shaft	Misc. Tools	62.00
1397-43	Gasket	Mold	350.00
1397-60-1	Clip	Dies	800.00
1397-61-1	Clip	Dies	450.00
1397-66	Gear	Mold	(See - 1397-153)
1397-73-1	End Bell	Mold	2,400.00
1397-74	Plate	Dr. Jig	165.00
1397-75	Flange	Dr. Jig	176.00
1397-86-1	Lamp - Red	Mold	)
1397-86-2	Lamp - Green	Mold	750.00)
1397-86-3	Lamp - White	Mold	)
1397-94-2	Cover - Top	Mold	2,873.00
1397-96	Shaft	Misc. Tools	75.00
1397-97	Hub-Rotor	Misc. Tools	25.00
1397-99	Bushing	Misc. Tools	30.00
1397-101	Bearing	Misc. Tools	25.00
1397-105	Mount	Misc. Tools	48.00
1397-106	Isolator	Mold	450.00
1397-112-2	Mounting Pl't.	Mold	1,200.00
1397-153-1	Gear	Mold	3,475.00
1397-154-1	Gear	Mold	(See - 1397-153)
1397-162	Stud	Misc. Tools	48.00
1397-163	Detent	Dies	350.00
1397-164-1	Lock	Die	200.00
1397-165-1	Stud	Misc. Tools	78.00
1397-166	Stud	Misc. Tools	78.00
1397-171	Insert	Misc. Tools	38.00
1397-172	Stud-Lamp	Misc. Tools	28.00
1397-173	Retainer-Lamp	Die	400.00
1397-174	Bracket-Relay	Misc. Tools	300.00
1397-175	Bracket	Die	235.00
1397-177	Printed Cir.	Art Work & Tools	210.00
1397-180	Name Plate	Art Work	25.00
1397-180-1	Name Plate	Art Work	25.00
1397-182	.5 Ω Resistor	Misc. Tools	35.00
1397-184	Pad.	Misc. Tools	—
1397-185	Bracket	Die	400.00
		Total	$23,275.00

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APPENDIX B

Photographs

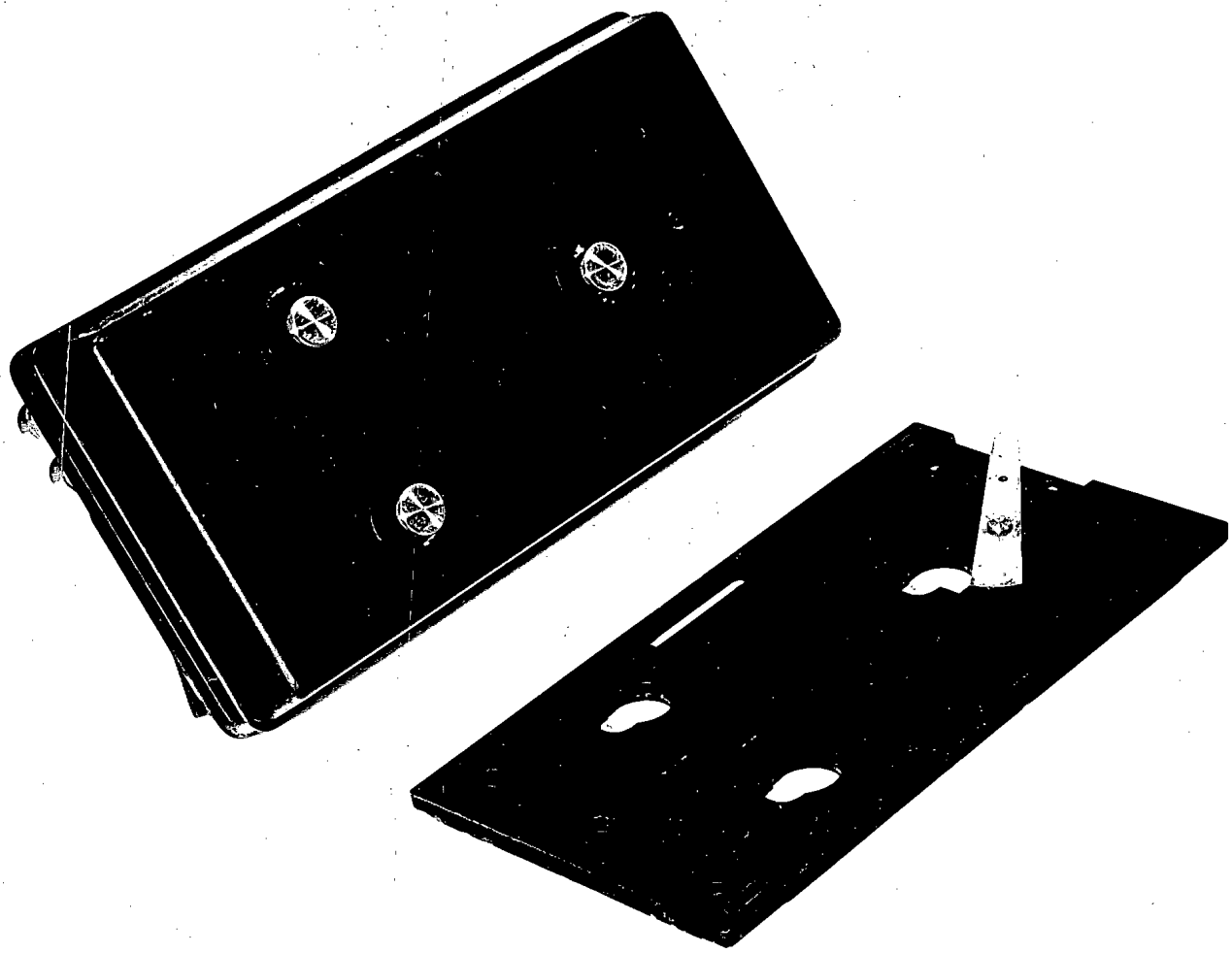

Figure 5 HG-3 Handcrank Generator - Mounting Discs

Figure 1 HG-3 Handcrank Generator - Handle in Place

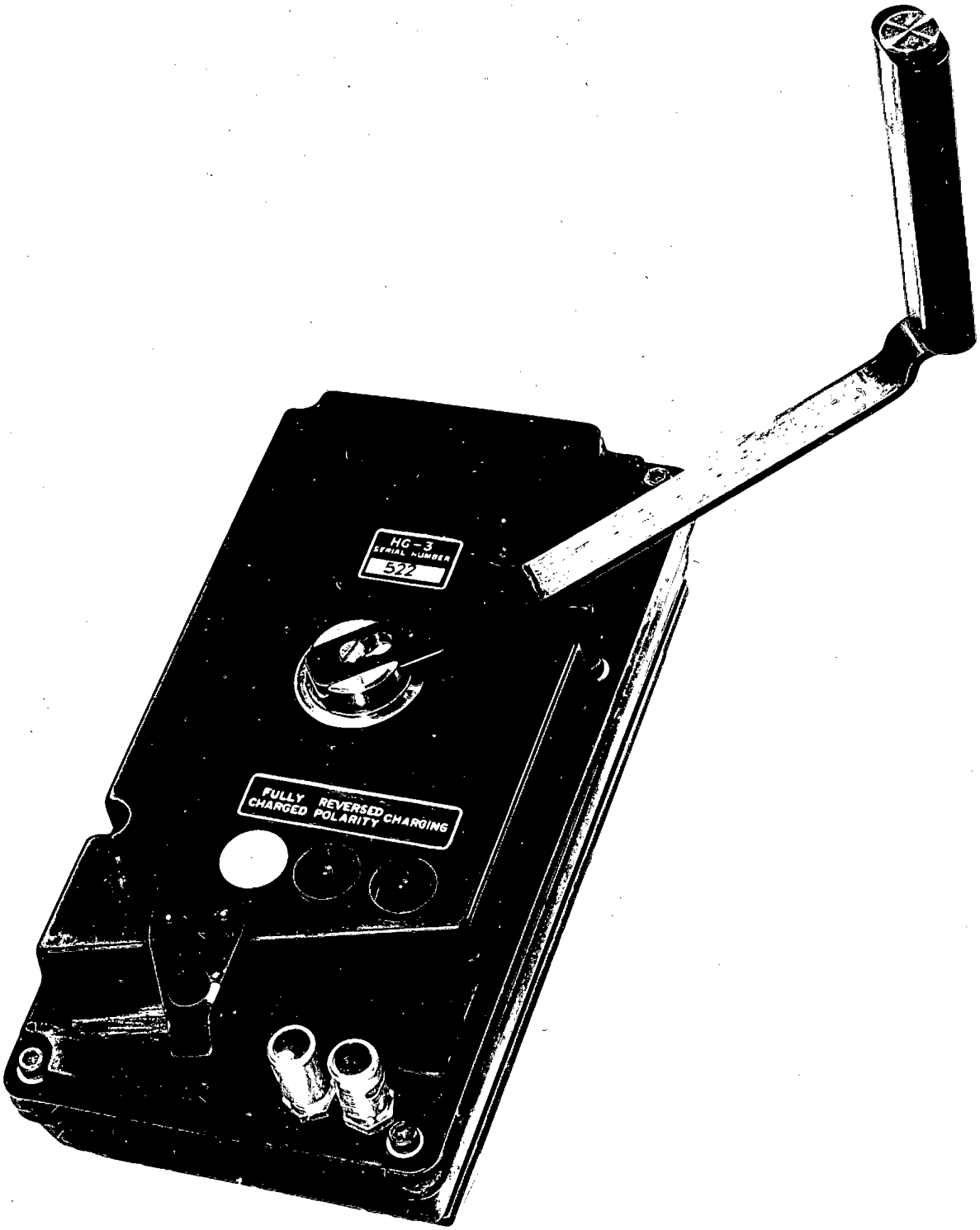

Figure 2 HG-3 Handcrank Generator - Handle in Cranking Position

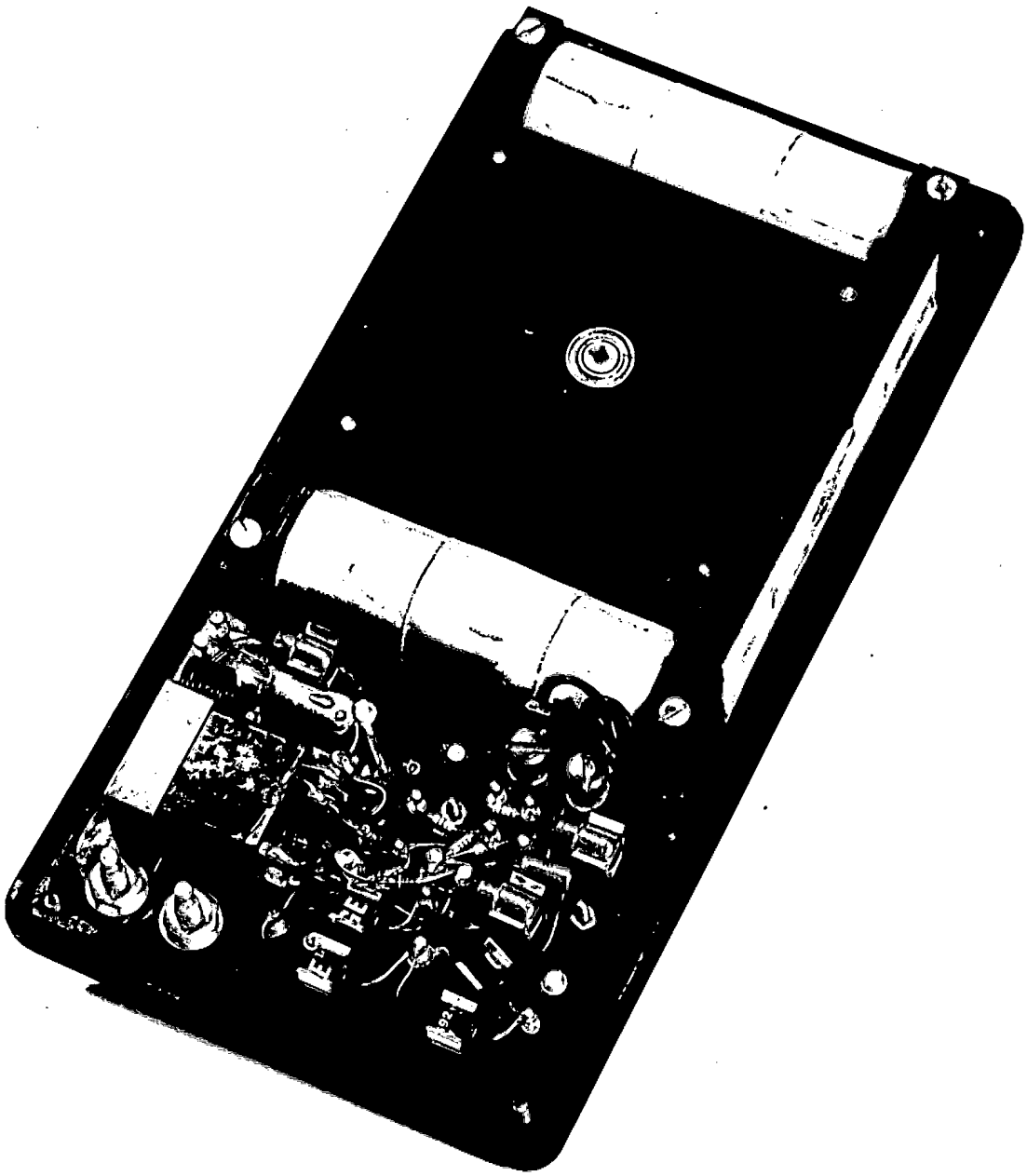

Figure 3 HG-3 Handcrank Generator - Cover Removed

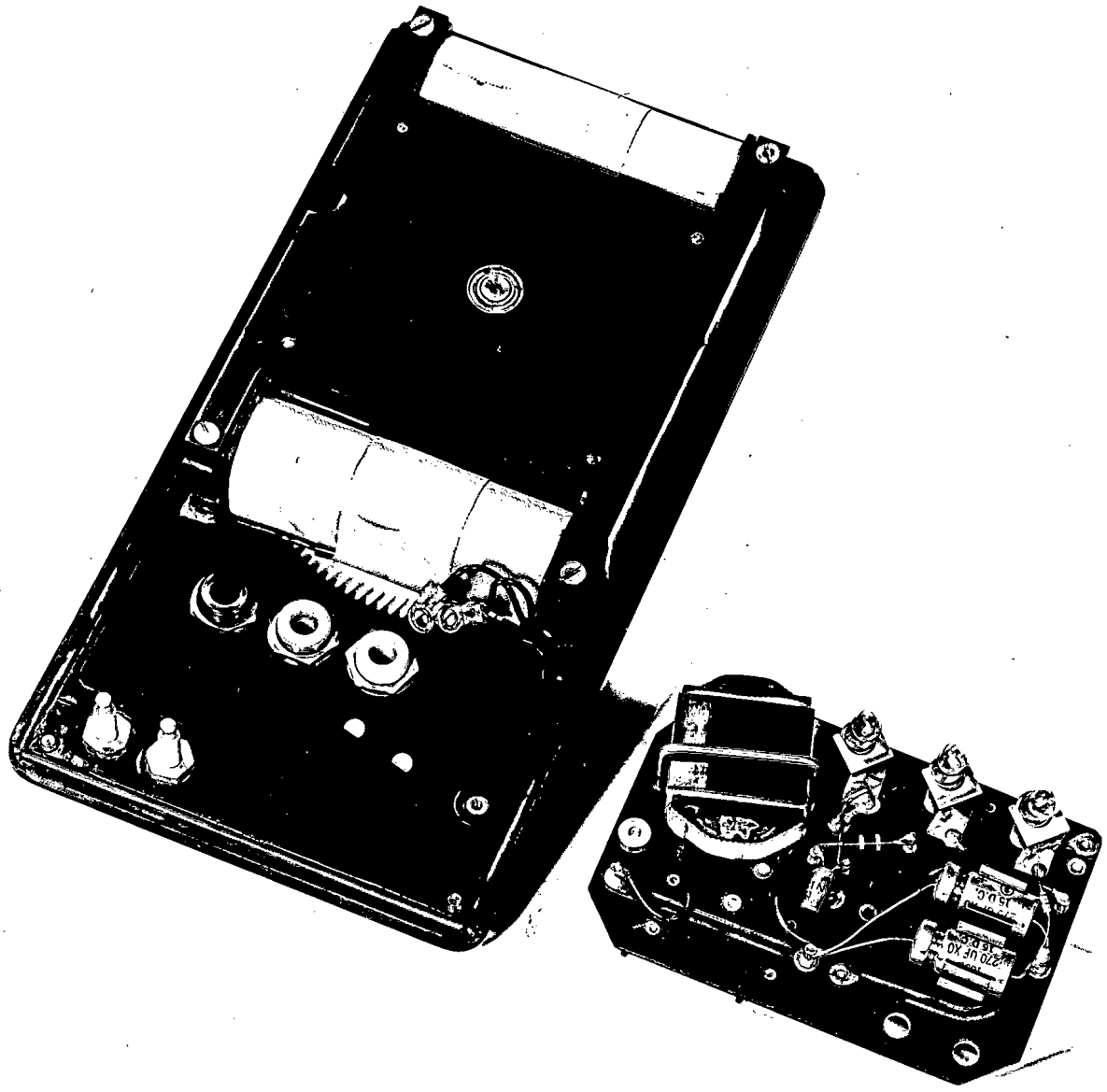

Figure 4 HG-3 Handcrank Generator - Electronics Package Removed